

CURRICULUM VITAE

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Education:

B.A. University of Maryland, College Park, MD
1972 Psychology
M.A. The American University, Washington, DC
1975 Experimental Psychology
Ph.D. The American University, Washington, DC
1977 Experimental Psychology

Professional Positions and Employment:

1977-1980 Postdoctoral Fellow, National Eye Institute, NIH
1980-1984 Staff Fellow, National Institute of Dental Research, NIH
1984-1989 Assistant Professor, Department of Stomatology, University of Montreal
1989-1993 Associate Professor, Department of Stomatology, University of Montreal
1993-1996 Professor, Department of Stomatology, University of Montreal
1996-2012 Harold Griffith Professor, Department of Anesthesiology, McGill University
1999-2003 Director, Anesthesia Research Unit, McGill University
2003-2009 Director, McGill Alan Edwards Centre for Research on Pain
2012-now Scientific Director, National Center for Complementary and Integrative Health

Other Experience and Professional Memberships (selected):

Prior to 2012:

Member of multiple editorial boards (*Journal of Neuroscience*, *Journal of Neurophysiology*, *Pain*, *Pain Forum*, *Clinical Journal of Pain*, *Experimental Brain Research*, *Pain Medicine*, *European Journal of Pain*)

Multiple activities within scientific societies: Society for Neuroscience (SfN) Program Committee, Scientific Publication Committee, Lindsley Prize Committee; International Association for the Study of Pain (IASP) Councilor, Treasurer, Editor-in-Chief of IASP Press; President of Canadian Pain Society

Served on review panels for the Canadian Institutes of Health Research (CIHR) and NIH (CIHR Behavioral Sciences Review Committee, NIH Somatosensory and Chemical Senses Study Section, Complementary and Alternative Medicine Study Section, NIH Program Project evaluation committee, NIH Special Review Committee on “Exploratory Studies in the Neurobiology of Pain in Sickle Cell Disease,” NIH Special Review Committee on “Vulvodynia”)

Member of advisory boards and boards of directors: Neuroscience Canada Science Advisory Council, Center for Neurovisceral Sciences and Women’s Health at UCLA, Parke-Davis Multidisciplinary Advisory Board, Louise and Alan Edwards Foundation Scientific Advisory Board and Board of Directors, Ultram ER 2006 Advisory Board, Canadian Pain Coalition Board of Directors, National Advisory Council for Complementary and Alternative Medicine, National Center for Complementary and Alternative Medicine (NCCAM)

Since 2012:

2012 Editor, Special Issue of *Neuroscience Letters* on Pain Imaging
2012-2016 Councilor, Society for Neuroscience
2013-now Scientific Advisor, Pain Research Forum
2013-2014 Chair, Online Programming Advisory Group, Society for Neuroscience
2013-2014 Member, History of SfN Working Group
2014-2015 Chair, Workforce and Training Working Group (Society for Neuroscience)
2014 Direct Submissions Editor, *Proceedings of the National Academy of Sciences (PNAS)*
2016-now Member, Editorial Board, *Neurobiology of Pain*
2017-2020 Member, Selection Committee, Eppendorf and Science Prize, *Science Magazine*

NIH Activities:

2012-now Scientific Director, Division of Intramural Research (DIR), NCCIH
2013-now Member, Pain Consortium Coordinating Committee
2013 Member, NIAAA Tenure-track Search Committee
2013-now Member, Combined Neuroscience IRB Steering Committee
2014 Co-Chair, NIH Research Festival
2015 Session Chair, 2015 Pain Consortium
2014-2015 Member, NIDCD Tenure-track Search Committee
2014-2015 Member, NIDCR Deputy Director Search Committee (2 searches)
2015 Vice-Chair, Stadtman Investigator Search Committee
2015 Member, NIH Director’s Lecture Committee
2015-now Member, NINDS Pre-IRB Scientific Review Committee

Honors and Awards:

2002 Distinguished Career Award, Canadian Pain Society
2003 Frederick W.L. Kerr Basic Science Research Award, American Pain Society
2005 James McGill Professorship, McGill University
2009 Canada Research Chair in Clinical Pain Research, McGill University
2014 John J. Bonica Distinguished Lecture Award, International Association for the Study of Pain

Invited Talks:

1980-2011: *More than 200 invited talks at professional meetings, universities, and companies.*

2012 New Jersey Dental School, Newark, New Jersey, “How psychological states affect pain”

- 2012 Webinar speaker, Canadian Institute for the Relief of Pain and Disability, “Outthinking pain—how the mind can control pain”
- 2012 McGill University Mini-Science Series, “How the mind can alter pain”
- 2012 Quebec Psychiatric Association meeting, Quebec City, “Imaging pain: from research to clinical application”
- 2012 NIH Pain Consortium Symposium, “Background and current hurdles in approaches for CAM therapies and cognitive biobehavioral therapy used for pain”
- 2012 IASP Orofacial Pain SIG Satellite Symposium, “Functional magnetic resonance imaging as a biomarker of orofacial pain”
- 2012 Washington University Neuroscience Retreat, St. Louis, Missouri, “Psychological control of pain and its disruption in chronic pain”
- 2012 Society for Neuroscience Neurobiology of Disease Workshop on “Persistent pain: Too much plasticity?”
- 2012 NINDS Grand Rounds, “Psychological control of pain and its disruption in chronic pain”
- 2013 American Association for Geriatric Psychiatry, “Imaging pain: From research to clinical applications”
- 2013 NCCAM Grand Rounds, “Neural basis of mind body pain therapies”
- 2013 Demystifying Medicine Series, NIH, “The neurobiology of pain”
- 2013 Uniformed Services University of the Health Sciences, Bethesda, Maryland, “Psychological control of pain and its disruption in chronic pain”
- 2013 American Pain Society NCCAM Workshop, “Neural basis of mind-body pain therapies”
- 2013 New York Academy of Sciences, New York City, Dr. Paul Janssen Award for Biomedical Research Symposium, “Understanding the neural basis of pain”
- 2014 IASP Research Symposium (Aarhus, Denmark)
- 2014 Pain and Itch Symposium (San Francisco, California)
- 2014 American Association for Orofacial Pain (Las Vegas, Nevada)
- 2014 International Research Congress on Integrative Medicine and Health (Miami, Florida)
- 2014 NIH Research Festival Symposium
- 2014 John J. Bonica Distinguished Lecture, IASP 15th World Congress on Pain, “Effect of environment on the long-term consequences of chronic pain” (Buenos Aires, Argentina)
- 2014 MD Neuroimaging Retreat, “Chronic pain alters the brain: can it be reversed by neuro-modulation?”
- 2015 Society for Urodynamics, Female Pelvic Medicine and Urogenital Reconstruction (SUFU), “The brains role in perceiving and modifying chronic pain” (Phoenix, Arizona)
- 2015 University of Arizona, “Effects of environment on chronic pain” (Tucson, Arizona)
- 2015 International Symposium on Malignant Mesothelioma Mesothelioma, “Mind-body practices and the brain’s role in the perception and management of pain” (Bethesda, Maryland)
- 2015 Facial Pain Research Foundation’s (FPRF) second Naples Neuroscience Research Institute, “From mice to men: The role of brain imaging in translational pain research” (Naples, Florida)
- 2015 SIMPAR 2015 meeting, “Chronic pain alters the brain: Can this be reversed by engaging pain-modulatory circuitry?” (Rome, Italy)
- 2015 American Pain Society Annual Scientific Meeting, “Effect of environment on the long-term consequences of chronic pain” & Refresher Course: “Pain101” (Palm Springs, California)
- 2015 European Pain Federation biennial Scientific meeting, “Physical activity and chronic pain” (Vienna, Austria)
- 2015 Invited speaker, University of British Columbia Neuroscience Research Colloquium, “Lifestyle and chronic pain” (December 2015, Vancouver, Canada)
- 2016 Invited Plenary Lecture, McGill Pain Day, “Lifestyle and chronic pain” (Montreal, Canada)
- 2016 Invited speaker, Georgetown University Mind Body Medicine Program, “Nonpharmacological modulation of chronic pain” (Washington, D.C.)
- 2016 Invited speaker, American Academy of Pain Management, “Nonpharmacological modulation of chronic pain” (San Antonio, Texas)
- 2016 Invited speaker, American Psychosomatic Society, “Nonpharmacological modulation of chronic pain” (New York City)

- 2017 Invited speaker, Challenge of Chronic Pain Conference, “Opioids in chronic pain and pleasant touch” (Wellcome Campus, Cambridge, UK)
- 2017 Invited speaker, SIMPAR, “Alternations of the opioid system in chronic pain” (Florence, Italy)
- 2017 Invited speaker, University of Pittsburgh, “Opioids in pain and pleasant touch” (Pittsburgh Pennsylvania)
- 2018 Invited speaker, Thompson Family Symposium, Columbia University (May 2018, New York City)
- 2018 Invited speaker, International Congress of Complementary and Integrative Health (May 2018, Baltimore, Maryland)
- 2018 Invited speaker, Philadelphia Pain Symposium (May 2018, Philadelphia, Pennsylvania)
- 2018 Invited speaker, Pain Mechanisms and Therapeutics Conference (June 2018, Taormina, Sicily)
- 2018 Invited speaker, NIH Veterinary Students Research Day (June 2018, NIH)
- 2018 Invited speaker, NINDS DIR Retreat (June 2018, NIH)
- 2018 Invited speaker, IASP Satellite Symposium on Chronic Pain: The Science of Complementary and Integrative Health Approaches (September 2018, Boston, Massachusetts)
- 2018 Invited speaker, IASP Refresher Course, Complementary and Integrative Approaches for Pain Management (September 2018, Boston, Massachusetts)
- 2018 Invited speaker, IASP Workshop, Music, the Brain and Chronic Pain
- 2018 Invited speaker, Chan-Zuckerberg Biohub Foundation Pain Workshop (September 2018, San Francisco, California)
- 2018 Invited speaker, California Pacific Medical Center Research Institute (September 2018, San Francisco, California)
- 2018 Invited speaker, SCD in Adults: Understanding pain and its mechanisms (October 2018, Bethesda, Maryland)
- 2018 Invited speaker, Society for Social Neuroscience (October 2018, San Diego, California)
- 2018 Invited speaker, Center for Brain and Pain, Boston Children’s Hospital (December 2018, Boston, Massachusetts)
- 2019 Invited speaker, University of Texas at Dallas (April 2019, Dallas, Texas)
- 2019 Invited speaker, Texas Tech University (April 2019, Lubbock, Texas)
- 2019 Symposium speaker, IASP Neuropathic Pain SIG Symposium (May 2019, London, UK)
- 2019 Invited speaker, Blaustein Pain Grand Rounds, Johns Hopkins University (May 2019, Baltimore, Maryland)

Contribution to Science:

1. Awake primate studies of nociceptive processing and behavioral modulation in thalamus

My early studies using extracellular recordings in behaving monkeys were the first to characterize thalamic nociceptive responses in the awake state and the modulation of these responses by psychological factors. We performed parallel psychophysical studies in macaque monkeys and human volunteers to demonstrate similarities in nociceptive and non-nociceptive discriminative ability and similar changes in discrimination by attentional state. We then studied single neurons in the monkey somatosensory thalamus and medial intralaminar nuclei to evaluate the underlying neuronal substrate of nociceptive discrimination and attentional modulation.

Selected publications:

Bushnell MC, Duncan GH, Dubner, R, Jones RL, Maixner W. Attentional influences on noxious and innocuous cutaneous heat detection in humans and monkeys. *J. Neurosci.* 5:1103-1110, 1985.

Bushnell MC, Duncan GH. Mechanical response properties of ventroposterior medial thalamic neurons in the alert monkey. *Exp. Brain Res.* 67:603-614, 1987.

Bushnell MC, Duncan GH. Sensory and affective aspects of pain perception: Is medial thalamus restricted to emotional issues? *Exp. Brain Res.* 78:415-418, 1989.

Bushnell MC, Duncan GH, Tremblay N. Thalamic VPM nucleus in the behaving monkey. I. Multimodal and discriminative properties of thermosensitive neurons. *J. Neurophysiol.* 69:739-752, 1993.

Tremblay N, Bushnell MC, Duncan GH. Thalamic VPM nucleus in the behaving monkey. II. Response to air-puff stimulation during discrimination and attention tasks. *J. Neurophysiol.* 69:753-763, 1993.

Duncan GH, Bushnell MC, Olivéras J-L, Bastrash N, Tremblay N. Thalamic VPM nucleus in the behaving monkey. III. Effects of reversible inactivation by lidocaine on thermal and mechanical discrimination. *J. Neurophysiol.* 70:2086-2096, 1993.

Craig D, Bushnell MC, Zhang, E-T, Blomqvist A. A specific thalamic nucleus for pain and temperature sensation in macaques and humans. *Nature* 372:770-773, 1994.

2. Pain processing and pain modulation in the human brain

My lab was the first to use brain imaging to examine pain processing in the human brain (*Science* 1992). Because of early Penfield studies in which pain was almost never evoked by direct cortical stimulation, neurology textbooks at the time described pain as a subcortical phenomenon, without cortical involvement. Our study, using PET blood flow imaging, showed that multiple cortical regions, including somatosensory and limbic areas, were activated by painful stimuli and shepherded in a new era of examining how pain is processed in the brain. My lab has continued to use human brain imaging along with detailed psychophysics to examine how pain is intrinsically modulated by cognitive and emotional factors.

Selected publications:

Talbot JD, Marrett S, Evans AC, Meyer E, Bushnell MC, Duncan GH. Multiple representations of pain in human cerebral cortex. *Science* 251:1355-1358, 1991.

Coghill RC, Talbot JD, Evans AC, Meyer E, Gjedde A, Bushnell MC, Duncan GH. Distributed processing of pain and vibration by the human brain. *J. Neurosci.* 14:4095-4108, 1994.

Craig AD, Bushnell MC. The thermal grill illusion: Unmasking the burn of cold pain. *Science* 265:252, 1994.

Craig AD, Reiman EM, Evans AC, Bushnell MC. Functional imaging of an illusion of pain. *Nature* 384:258-260, 1996.

Rainville P, Duncan GH, Price DD, Carrier B, Bushnell MC. Pain affect coded in human anterior cingulate but not somatosensory cortex. *Science* 227:968-971, 1997.

Hofbauer, RK, Rainville P, Duncan GH, Bushnell MC. Cortical representation of the sensory dimension of the pain experience. *J. Neurophysiol.* 86:402-411, 2001.

Strigo IA, Duncan GH, Boivin M, Bushnell MC. Differentiation of visceral and cutaneous pain in human cerebral cortex. *J. Neurophysiol.* 89:3294-3303, 2003.

Schweinhardt P, Semonowicz DA, Jaeger E, Duncan GH, Bushnell MC. The anatomy of the mesolimbic reward system: a link between personality and the placebo analgesic response. *J. Neurosci.* 29:4882, 2009.

Villemure C, Ceko M, Cotton VA, Bushnell MC. Insular cortex mediates increased pain tolerance in yoga practitioners. *Cerebral Cortex* 2013.

Čeko M, Gracely JL, Fitzcharles MA, Seminowicz DA, Schweinhardt P, Bushnell MC. Is a responsive default mode network required for successful working memory task performance? *J Neurosci.* 235, 2015.

Villemure C, Čeko M, Cotton VA, Bushnell MC. Neuroprotective effects of yoga practice: age-, experience-, and frequency-dependent plasticity. *Front Hum Neurosci.* 12;9:281, 2015.

3. Effect of chronic pain on the brain

My lab has shown in pain patients and animal models that chronic pain can have important effects on the physiology and anatomy of the brain. We were one of the first labs to show altered pain processing related to allodynia in pain patients and to show reduced cortical gray matter in pain patients. We were the first to show altered dopamine function in pain patients and to demonstrate gray matter changes in rodent models.

Selected publications:

Hofbauer RK, Olausson H, Bushnell MC. Peripheral and central mechanisms underlying tactile allodynia in a nerve-injured patient. *Clin. J. Pain* 22:104-108, 2006.

Villemure C, Wassimi S, Bennett, GJ, Shir Y, Bushnell MC. Unpleasant odors increase pain processing in a patient with neuropathic pain: Psychophysical and fMRI investigation. *Pain* 120:213-220, 2006.

Wood PB, Schweinhardt P, Bushnell MC, Jaeger E, Dagher A, Hakyemez H, Rabiner EA, Chizh BA. Fibromyalgia patients show an abnormal dopamine response to pain. *Eur. J. Neurosci.* 25:3576-3582, 2007.

Kuchinad A, Schweinhardt P, Seminowicz DA, Wood P, Chizh BA, Bushnell MC. Accelerated brain gray-matter loss in fibromyalgia patients: Premature aging of the brain? *J. Neurosci.* 27:4004-4007, 2007.

Seminowicz DA, Laferriere AL, Millecamps M, Yu JSC, Coderre TJ, Bushnell MC. MRI structural brain changes associated with sensory and emotional function in a rat model of long-term neuropathic pain. *NeuroImage* 47(3):1007-14, 2009.

Seminowicz DA, Labus JB, Bueller JA, Tillisch K, Naliboff BD, Bushnell MC, Mayer EA. MRI morphometric and cortical thickness analysis in irritable bowel syndrome. *Gastroenterology* 139:48-57, 2010.

Ceko M, Bushnell MC, Fitzcharles MA, Schweinhardt P. Fibromyalgia interacts with age to change the brain. *Neuroimage: Clinical* 3:249-60, 2013.

Thompson SJ, Millecamps M, Allaga A, Seminowicz DA, Low LA, Bedell BJ, Stone LS, Schweinhardt P, Bushnell MC. Metabolic brain activity suggestive of persistent pain in a rat model of neuropathic pain. *Neuroimage* 91:344-52, 2014.

Low LA, Bauer LC, Pitcher MH, Bushnell MC. Restraint training for awake functional brain scanning of rodents can cause long-lasting changes in pain and stress responses. *Pain* 157(8):1761-72, 2016.

Pitcher MH, Tarum F, Rauf IZ, Low LA, Bushnell MC. Modest amounts of voluntary exercise reduce pain- and stress-related outcomes in a rat model of persistent hind limb inflammation. *J. Pain* 18:687-701, 2017.

Thompson SJ, Pitcher MH, Stone LS, Tarum F, Niu G, Chen X, Kiesewetter DO, Schweinhardt P, Bushnell MC. Chronic neuropathic pain reduces opioid receptor availability with associated anhedonia in rat. *Pain* 159:1856-1866, 2018.

4. Neural underpinnings of affective touch

Touch, like pain, is highly modulated by psychological state. There is accumulating evidence that affective aspects of touch are subserved by a little-understood pathway involving low threshold C fibers. In collaboration with Swedish colleagues, we have studied affective touch in humans and rodent models and found a separation of affective and discriminative touch processing, similar to what we have found for pain.

Selected publications:

Olausson H, Lamarre Y, Backlund H, Morin C, Wallin BG, Starck G, Ekholm S, Strigo I, Worsley K, Vallbo AB, Bushnell MC. Unmyelinated tactile afferents signal touch and project to insular cortex. *Nature Neuroscience* 5:900-4, 2002.

Ceko M, Seminowicz DA, Bushnell MC, Olausson HW. Anatomical and functional enhancements of the insula after loss of large primary somatosensory fibres. *Cerebral Cortex* 23(9):2017-24, 2013.

Liljencrantz J, Bjornsdotter M, Morrison I, Bergstrand S, Ceko M, Seminowicz D, Cole J, Bushnell MC, Olausson O. Altered C-tactile processing in human dynamic tactile allodynia. *Pain* 154:227-234, 2013.

Case LK, Čeko M, Gracely JL, Richards EA, Olausson H, Bushnell MC. Touch perception altered by chronic pain and by opioid blockade. *eNeuro*. 10;3(1), 2016.

Case LK, Laubacher CM, Olausson H, Wang B, Spagnolo PA, Bushnell MC. Encoding of touch intensity but not pleasantness in human primary somatosensory cortex. *J Neurosci*. 36(21):5850-60, 2016.

Case LK, Laubacher CM, Richards EA, Spagnolo PA, Olausson H, Bushnell MC. Inhibitory rTMS of secondary somatosensory cortex reduces intensity but not pleasantness of gentle touch. *Neurosci. Lett*. 653:84-91, 2017.

Szczot M, Liljencrantz J, Ghitani N, Barik A, Lam R, Thompson JH, Bharucha-Goebel D, Saade D, Necaie A, Donkervoort S, Foley AR, Gordon T, Case L, Bushnell MC, Bonnemann CG, Chesler AT. PIEZO2 mediates injury-induced tactile pain in mice and humans. *Science Translational Medicine* 10, 2018.

Nagi SS, Marshall AG, Makdani A, Jarocka E, Liljencrantz J, Ridderstrom M, Shaikh S, O'Neill F, Saade D, Donkervoort S, Foley AR, Minde J, Trulsson M, Cole J, Bonnemann CG, Chesler AT, Bushnell MC, McGlone F, Olausson H. An ultrafast system for signaling mechanical pain in human skin. *Sci. Adv.* 5:eaaw1297, 2019.